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COMPENSATION OF SPACE-CHARGE MISMATCH AT TRANSITION OF BOOSTER USING THE TRANSITION-JUMP METHOD

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This method was applied successfully[1] on the CERN PS. Its application to the NAL accelerators was studied by E. Courant.[2] A theoretical analysis of this method was made by D. Möhl.[3] A more detailed design of such a system for the NAL booster synchrotron is given here based on Möhl's analysis.

Möhl's Analysis

The qualitative and approximate quantitative results of Möhl's analysis are summarized below.

1. The transition-jump method is effective to partially compensate for the phase-space mismatch caused by space charge at transition which becomes prominent for $\eta_o(0) >> 1$. For best overall matching one needs a delayed jump which starts near transition ($x_1 \sim 0$ in Möhl's notation). This and $\eta_o(0) >> 1$ are assumed for all subsequent formulas.

2. Bunch-length matching for an infinitely fast jump gives a lower limit for the magnitude of the jump

$$\frac{\delta\gamma_t}{\delta\gamma} \gtrsim 1.5\ (\eta_o(0))^{4/3} \qquad (1)$$

where $\delta\gamma_t$ is the jump of the transition γ, and $\delta\gamma \equiv \dot{\gamma}\, T$ (T = time interval about transition in which the adiabatic approximation is not valid). $\delta\gamma$ is, therefore, the range of γ about transition in which the adiabatic approximation is not valid.

3. For finite jump speed $\left(|\dot{\gamma}_t| \neq \infty\right)$ the increase in phase area A is given by $\left(\frac{\delta A}{A} << 1\right)$

$$\frac{\delta A}{A} \sim \frac{0.60}{(\eta_o(0))^{2/3}} \quad \frac{\left(\frac{\delta\gamma_t}{\delta\gamma}\right)^2}{\left(1 + \frac{|\dot{\gamma}_t|}{\dot{\gamma}}\right)^{4/3}} \tag{2}$$

which gives the desired jump speed $\dot{\gamma}_t$. If $\frac{\delta\gamma_t}{\delta\gamma}$ is given by Equ. (1) we have

$$\frac{\delta A}{A} \sim 1.4 \quad \frac{(\eta_o(0))^2}{\left(1 + \frac{|\dot{\gamma}_t|}{\dot{\gamma}}\right)^{4/3}} \tag{3}$$

4. The growth in $\left(\frac{\Delta p}{p}\right)_{max} \equiv \Delta$ is given by

$$\frac{\Delta}{\Delta_o} \sim (\eta_o(0))^{-1/3} \left[1 + 0.63\, \eta_o(0) \frac{\frac{\delta\gamma_t}{\delta\gamma}}{\left(1 + \frac{|\dot{\gamma}_t|}{\dot{\gamma}}\right)^{2/3}}\right] \tag{4}$$

where Δ_o is the $\frac{\Delta p}{p}$ at transition in the absence of space charge. If $\frac{\delta\gamma_t}{\delta\gamma}$ is given by Equ. (1) we have

$$\frac{\Delta}{\Delta_o} \sim (\eta_o(0))^{-1/3} + 0.95 \quad \frac{(\eta_o(0))^2}{\left(1 + \frac{|\dot{\gamma}_t|}{\dot{\gamma}}\right)^{2/3}} \tag{5}$$

Booster Parameters

The transition parameters $\eta_o(0)$ and T can be given in terms of dimensionless parameters by[4]

$$\eta_o(0) = \frac{\sqrt{3}\ \pi^{7/2}}{2\ (\Gamma(2/3))^3}\ \frac{r_p}{R}\ \frac{Ng_o}{A^{3/2}}\ \left(\frac{f_{rf}}{\dot{\gamma}}\right)^{1/2} \tag{6}$$

$$T^3 = \frac{1}{4\pi}\ \frac{\gamma^4}{f_{rf}\ \dot{\gamma}^2 |\cot\phi_s|} \tag{7}$$

where for the booster at transition the parameters are

$\Gamma(2/3)$ = factorial function of 2/3 = 1.354

r_p = classical proton radius = 1.53×10^{-18} m

R = machine radius = 75.47 m

N = total number of protons per pulse = 3.5×10^{12}

g_o = geometric factor $\sim$ 4.5

f_{rf} = rf frequency = $52.20 \times 10^6\ \text{sec}^{-1}$

$\dot{\gamma} \equiv$ time rate of increase of γ = $0.407 \times 10^3\ \text{sec}^{-1}$

ϕ_s = synchronous phase = $90^\circ \pm 20^\circ$

A = total phase area occupied by beam in $\frac{p}{mc}\ \phi$ units ($A = \frac{hS}{mcR}$ where S = phase area of each beam bunch in $w\phi$ units, and $dw = \frac{R}{h}\ dp$) = 0.0069

With these parameters we have for the booster

$\eta_o(0) = 3.8$

$T = 0.28 \times 10^{-3}$ sec

$\delta\gamma = \dot{\gamma}T = 0.114$

and Equ. (1) gives

$$\boxed{\delta\gamma_t \sim 1.0} \tag{8}$$

For $\frac{|\dot{\gamma}_t|}{\dot{\gamma}}$ = 10 and 20, Equ. (3) gives $\frac{\delta A}{A}$ = 0.83 and 0.35. Therefore a jump speed of

$$\boxed{|\dot{\gamma}_t| \sim 10^4 \text{ sec}^{-1}} \tag{9}$$

or a jump time for $\delta\gamma_t$ = 1.0 of 0.1 m sec is desirable. This jump speed gives $\frac{|\dot{\gamma}_t|}{\dot{\gamma}} \cong 25$ and

$$\boxed{\frac{\delta A}{A} \sim 0.26, \qquad \frac{\Delta}{\Delta_o} \sim 2.2} \tag{10}$$

γ_t-jump Quadrupoles

Q-jump is a misleading name for the system. What one wants is a γ_t-jump system, and it is quite possible to shift γ_t by 1 unit without noticeably affecting ν_x and ν_y (or Q_x and Q_y). To see this we recall that the equation for the dispersion function x_p after Floquet transformation is

$$\frac{d^2u}{d\phi^2} + \nu^2 u = \frac{(\nu\beta)^{3/2}}{R} \tag{11}$$

where

$$\begin{cases} u = \dfrac{x_p}{\sqrt{\nu\beta}} \\ d\phi = \dfrac{dz}{\nu\beta}, \quad z \text{ along orbit} \end{cases}$$

If we add to β a term with zero ϕ-average (say, $\frac{a}{\nu}\sin n\phi$), the betatron wave numbers ν_x and ν_y will not be affected. Neglecting other oscillatory terms in β and assuming $\frac{a}{R} << 1$ we can write approximately

$$\frac{1}{R}(\nu\beta)^{3/2} = \frac{1}{R}(R + a\sin n\phi)^{3/2} = \sqrt{R} + \frac{3}{2}\frac{a}{\sqrt{R}}\sin n\phi$$

The solution of Equ. (11) is then

$$u = \frac{\sqrt{R}}{\nu^2} + \frac{3}{2}\frac{\frac{a}{\sqrt{R}}}{\nu^2 - n^2}\sin n\phi$$

The change in orbit length per unit $\frac{\Delta p}{p}$ is

$$\delta L = \oint \frac{x_p}{R}\,dz = \oint \frac{1}{R}(\nu\beta)^{3/2}\,u\,d\phi$$

$$= \oint \left[\frac{R}{\nu^2} + \frac{3}{2}a\left(\frac{1}{\nu^2} + \frac{1}{\nu^2 - n^2}\right)\sin n\phi + \frac{9}{4}\frac{a^2}{R}\frac{1}{\nu^2 - n^2}\sin^2 n\phi\right] d\phi$$

$$= \frac{2\pi R}{\nu^2}\left(1 + \frac{9}{8}\frac{a^2}{R^2}\frac{\nu^2}{\nu^2 - n^2}\right)$$

The transition γ_t is, therefore, changed to

$$\gamma_t^2 = \frac{2\pi R}{\delta L} \cong \nu^2 - \frac{9}{8}\frac{a^2}{R^2}\frac{\nu^4}{\nu^2 - n^2} \qquad (12)$$

If n is chosen to be the integer closest to ν, because of the large factor $\frac{\nu^4}{\nu^2 - n^2}$ a small $\frac{a}{R}$ is adequate to reduce γ_t a great deal.

For the NAL booster the number of cells is N = 24 and ν (namely ν_x) is 6.7. We choose n = 6 because it is commensurable with N. Twelve 0.20 m long quadrupoles are placed in the mid-F positions (the cell structure is FOFDOOD) and evenly spaced around the ring. With the 12 quadrupoles excited alternately as F and D, computer runs using SYNCH give for various values of B' of the quadrupoles the following values of ν_x, ν_y, γ_t, and $x_{p\ max}$ at transition.

B' (kG/m)	ν_x	ν_y	$x_{p\ max}$(m)	γ_t
0	6.700	6.800	3.189	5.446
±2.825	6.701	6.800	4.157	5.425
±8.476	6.710	6.800	5.966	5.267
±14.127	6.729	6.801	7.512	5.008
±19.777	6.755	6.802	8.728	4.715
±25.428	6.790	6.803	9.600	4.435
±31.079	6.832	6.804	10.156	4.191

We see, therefore, with very modest quadrupole strength one can reduce γ_t by 1 unit. Of course in so doing $x_{p\ max}$ is increased by a factor of 3. This increase is, of course, unavoidable but it is quite tolerable. The SYNCH output for the cases of B' = 0 and 25.428 kG/m are attached as an appendix.

Acknowledgment

Several interesting discussions with Lloyd Smith were very helpful. The SYNCH runs were made by G. Bellendir.

SYNCH RUN SYNC BOOSTER TRANSITION JUMP $B' = 25.428$ kG/m

```
*** G       =            // 45.0          (25.428)  } corresponding values at transition given in parentheses
*** BRHO    =            // 296.500908    (167.543) }
*** D       DRF          // 0.5
*** DD      DRF          // 1.2
*** DDD     DRF          // 6.0
*** BF      MAG          // 2.889612   16.076368 BRHO     7.258835   0.0     0.0
*** BD      MAG          // 2.889612  -17.110279BRHO      6.172722   0.0     0.0
*** QF      MAG          // 0.2        G         BRHO     0.0        0.0     0.0
*** QD      MAG          // 0.2        -G        BRHO     0.0        0.0     0.0
*** C       CYA   36   1 // BF  D    QF  D    BF  D    BD  DDD  BD  D    BF  DD
    *                    // BF  D    BD  DDD  BD  D    BF  D    DD  D    BF  D
    *                    // BD  DDD  BD  D    BF  DD   BF  D    BD  DDD  BD  D
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BETATRON FUNCTIONS THROUGH $C = .\frac{1}{6}$ of ring

CYCLE I	S	NAME	PSIX/2PI	BETAX	ALPHAX	XEQ	DXEQ	WX	PSIY/2PI	BETAY	ALPHAY	YEQ	DYEQ	WY
1	0.0	BF	0.0	20.01089	-4.12780	-3.17636	-0.76019	4.47335	0.0	11.37857	2.23539	0.0	0.0	3.37321
2	2.88961	D	0.01589	35.94996	-0.53352	-4.41856	-0.06761	5.99583	0.06605	5.23730	0.19603	0.0	0.0	2.28451
3	3.38961	QF	0.01809	36.49241	-0.55139	-4.45236	-0.06761	6.04089	0.08149	5.09083	0.09690	0.0	0.0	2.25629
4	3.58961	D	0.01896	36.49241	0.55139	-4.45236	0.06761	6.04089	0.08775	5.09083	-0.09690	0.0	0.0	2.25629
5	4.08961	BF	0.02116	35.94996	0.53352	-4.41856	0.06761	5.99583	0.10318	5.23730	-0.19603	0.0	0.0	2.28451
6	6.97922	D	0.03705	20.01089	4.12780	-3.17636	0.76019	4.47335	0.16924	11.37857	-2.23539	0.0	0.0	3.37321
7	7.47922	BD	0.04149	16.10846	3.67707	-2.79626	0.76019	4.01353	0.17560	13.74572	-2.49891	0.0	0.0	3.70752
8	10.36884	DDD	0.09664	5.25677	0.66553	-1.03102	0.51100	2.29277	0.20005	22.03020	0.11310	0.0	0.0	4.69363
9	16.36884	BD	0.31361	7.15205	-0.98141	2.03500	0.51100	2.67433	0.24365	22.32801	-0.16274	0.0	0.0	4.72525
10	19.25845	D	0.35412	21.54309	-4.77757	4.23286	1.07173	4.64145	0.26761	14.12363	2.52548	0.0	0.0	3.75814
11	19.75845	BF	0.35744	26.59714	-5.33053	4.76872	1.07173	5.15724	0.27380	11.72875	2.26428	0.0	0.0	3.42473
12	22.64806	DD	0.36956	46.47099	-0.48150	6.69372	0.21107	6.81696	0.33712	5.50239	0.20083	0.0	0.0	2.34572
13	23.84806	BF	0.37362	47.66475	-0.51331	6.94701	0.21107	6.90397	0.37281	5.29266	-0.02605	0.0	0.0	2.30058
14	26.73767	D	0.38461	31.48813	5.24409	6.09570	-0.77838	5.61143	0.44291	10.06943	-1.86514	0.0	0.0	3.17324
15	27.23767	BD	0.38737	26.47032	4.79153	5.70651	-0.77838	5.14493	0.45014	12.04577	-2.08753	0.0	0.0	3.47070
16	30.12728	DDD	0.41454	12.78927	0.68331	4.79504	0.12201	3.57621	0.47848	18.76660	0.15203	0.0	0.0	4.33204
17	36.12728	BD	0.51072	8.71867	-0.00488	5.52711	0.12201	2.95274	0.59008	18.90487	-0.17508	0.0	0.0	4.34797
18	39.01690	D	0.55508	14.79800	-2.42793	7.38484	1.21579	3.84682	0.55811	12.22122	2.09987	0.0	0.0	3.49589
19	39.51690	BF	0.56005	17.34241	-2.66090	7.99273	1.21579	4.16442	0.56523	10.23201	1.87855	0.0	0.0	3.19875
20	42.40651	D	0.58052	25.06804	0.40157	9.60027	-0.14453	5.00680	0.63388	5.41573	0.02828	0.0	0.0	2.32717
21	42.90651	QD	0.58372	24.67806	0.37841	9.52800	-0.14453	4.96770	0.64857	5.43365	-0.06412	0.0	0.0	2.33102
22	43.10651	D	0.58501	24.67806	-0.37841	9.52800	0.14453	4.96770	0.65443	5.43365	0.06412	0.0	0.0	2.33102
23	43.60651	BF	0.58825	25.06804	-0.40157	9.60027	0.14453	5.00680	0.66912	5.41573	-0.02828	0.0	0.0	2.32717
24	46.49612	D	0.60868	17.34241	2.66090	7.99273	-1.21579	4.16442	0.73778	10.23201	-1.87855	0.0	0.0	3.19875
25	46.99612	BD	0.61365	14.79800	2.42793	7.38484	-1.21579	3.84682	0.74490	12.22122	-2.09987	0.0	0.0	3.49589
26	49.88573	DDD	0.65801	8.71867	0.00488	5.52711	-0.12201	2.95274	0.77292	18.90487	0.17508	0.0	0.0	4.34797
27	55.88573	BD	0.75419	12.78927	-0.68331	4.79504	-0.12201	3.57621	0.82452	18.76660	-0.15203	0.0	0.0	4.33204
28	58.77534	D	0.78136	26.47032	-4.79153	5.70651	0.77838	5.14493	0.85286	12.04577	2.08753	0.0	0.0	3.47070
29	59.27534	BF	0.78412	31.48813	-5.24409	6.09570	0.77838	5.61143	0.86009	10.06943	1.86514	0.0	0.0	3.17324
30	62.16496	DD	0.79511	47.66475	0.51331	6.94701	-0.21107	6.90397	0.93019	5.25266	0.02605	0.0	0.0	2.30058
31	63.36496	BF	0.79917	46.47099	0.48150	6.69372	-0.21107	6.81696	0.96588	5.50239	-0.20083	0.0	0.0	2.34572
32	66.25457	D	0.81129	26.59714	5.33053	4.76872	-1.07173	5.15724	1.02921	11.72875	-2.26428	0.0	0.0	3.42473
33	66.75457	BD	0.81461	21.54309	4.77757	4.23286	-1.07173	4.64145	1.03539	14.12363	[illegible].52548	0.0	0.0	3.75814
34	69.64418	DDD	0.85512	7.15205	0.98141	2.03500	-0.51100	2.67433	1.05935	22.32801	0.16274	0.0	0.0	4.72525
35	75.64418	BD	1.07209	5.25677	-0.66553	-1.03102	-0.51100	2.29277	1.10295	22.03020	-0.11310	0.0	0.0	4.69363
36	78.53379	D	1.12724	16.10846	-3.67707	-2.79626	-0.76019	4.01353	1.12740	13.74572	2.49891	0.0	0.0	3.70752
37	79.03379	BF	1.13168	20.01089	-4.12780	-3.17636	-0.76019	4.47335	1.13377	11.37857	2.23539	0.0	0.0	3.37321

QX = 1.13167642 XRMS = 5.87279489 QY = 1.13336572 YRMS = 0.0
TRANSITION GAMMA = 4.435177

```
*** D       CYA    6   1 // C   C   C   C   C   C
```

SYNCH RUN SYNC   BOOSTER TRANSITION JUMP $B' = 0$ kG/m

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*** G      =           // 0.0           (0.0)     } corresponding values at transition given in parentheses
*** BRHO   =           // 296.500908    (167.543) }
*** D      DRF         // 0.5
*** DD     DRF         // 1.2
*** DDD    DRF         // 6.0
*** BF     MAG         // 2.889612   16.076368 BRHO     7.258835  0.0     0.0
*** BD     MAG         // 2.889612  -17.110279 BRHO     6.172722  0.0     0.0
*** QF     MAG         // 0.2        G         BRHO     0.0       0.0     0.0
*** QD     MAG         // 0.2       -G         BRHO     0.0       0.0     0.0
*** C      CYA   36  1 // BF  D    QF  D    BF  D   BD  DDD  BD  D    BF  DD
  *                    // BF  D    BD  DDD  BD  D   BF  D    QD  D    BF  D
  *                    // BD  DDD  BD  D    BF  DD  BF  C    BD  DDD  BD  D
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BETATRON FUNCTIONS THROUGH C = .$\frac{1}{6}$ of ring

CYCLE	S	NAME	PSIX/2PI	BETAX	ALPHAX	XEQ	DXEQ	NX	PSIY/2PI	BETAY	ALPHAY	YEQ	DYEQ	NY
1	0.0	BF	0.0	20.88147	-3.75875	2.59227	0.39762	4.56962	0.0	10.82229	2.05608	0.0	0.0	3.28973
2	2.88961	D	0.01608	33.67330	0.01782	3.18895	-0.00000	5.80287	0.06713	5.34167	0.11378	0.0	0.0	2.31120
3	3.38961	QF	0.01844	33.66290	0.00297	3.18855	-0.00000	5.80197	0.08214	5.27530	0.01896	0.0	0.0	2.29680
4	3.58961	D	0.01939	33.66290	-0.00297	3.18895	-0.00000	5.80197	0.08818	5.27530	-0.01896	0.0	0.0	2.25680
5	4.08961	BF	0.02175	33.67330	-0.01782	3.18895	-0.00000	5.80287	0.10319	5.34167	-0.11378	0.0	0.0	2.31120
6	6.97922	D	0.03783	20.88147	3.75875	2.59227	-0.39762	4.56962	0.17032	10.82229	-2.05608	0.0	0.0	3.28973
7	7.47922	BD	0.04202	17.30384	3.39651	2.39346	-0.39762	4.15979	0.17703	12.99913	-2.29760	0.0	0.0	3.60543
8	10.36884	DDD	0.08597	7.59169	0.49008	1.84131	0.00000	2.75530	0.20314	20.45662	0.14995	0.0	0.0	4.52290
9	16.36884	BD	0.23102	7.59169	-0.49008	1.84131	0.00000	2.75530	0.25051	20.45662	-0.14995	0.0	0.0	4.52290
10	19.25845	D	0.27498	17.30384	-3.39651	2.39346	0.39762	4.15979	0.27662	12.99913	2.29760	0.0	0.0	3.60543
11	19.75845	BF	0.27916	20.88147	-3.75875	2.59227	0.39762	4.56962	0.28333	10.82229	2.05608	0.0	0.0	3.28973
12	22.64806	D	0.29524	33.67330	0.01782	3.18895	0.00000	5.80287	0.35046	5.34167	0.11378	0.0	0.0	2.31120
13	23.14806	BF	0.30092	33.67330	-0.01782	3.18895	0.00000	5.80287	0.38652	5.34167	-0.11378	0.0	0.0	2.31120
14	26.73767	D	0.31699	20.88147	3.75875	2.59227	-0.39762	4.56962	0.45365	10.82229	-2.05608	0.0	0.0	3.28973
15	27.23767	BD	0.32118	17.30384	3.39651	2.39346	-0.39762	4.15979	0.46036	12.99913	-2.29760	0.0	0.0	3.60543
16	30.12728	DDD	0.36514	7.59169	0.49008	1.84131	0.00000	2.75530	0.48647	20.45662	0.14995	0.0	0.0	4.52290
17	36.12728	BD	0.51019	7.59169	-0.49008	1.84131	0.00000	2.75530	0.53385	20.45662	-0.14995	0.0	0.0	4.52290
18	39.01690	D	0.55414	17.30384	-3.39651	2.39346	0.39762	4.15975	0.55996	12.99913	2.29760	0.0	0.0	3.60543
19	39.51690	BF	0.55833	20.88147	-3.75875	2.59227	0.39762	4.56962	0.56667	10.82229	2.05608	0.0	0.0	3.28973
20	42.40651	D	0.57441	33.67330	0.01782	3.18895	0.00000	5.80287	0.63380	5.34167	0.11378	0.0	0.0	2.31120
21	42.90651	QD	0.57677	33.66290	0.00297	3.18895	0.00000	5.80197	0.64881	5.27530	0.01896	0.0	0.0	2.29680
22	43.10651	D	0.57772	33.66290	-0.00297	3.18895	0.00000	5.80197	0.65485	5.27530	-0.01896	0.0	0.0	2.25680
23	43.60651	BF	0.58008	33.67330	-0.01782	3.18895	0.00000	5.80287	0.66986	5.34167	-0.11378	0.0	0.0	2.31120
24	46.49612	D	0.59616	20.88147	3.75875	2.59227	-0.39762	4.56962	0.73695	10.82229	-2.05608	0.0	0.0	3.28973
25	46.99612	BD	0.60034	17.30384	3.39651	2.39346	-0.39762	4.15979	0.74370	12.99913	-2.29760	0.0	0.0	3.60543
26	49.88573	DDD	0.64430	7.59169	0.49008	1.84131	0.00000	2.75530	0.76981	20.45662	0.14995	0.0	0.0	4.52290
27	55.88573	BD	0.78935	7.59169	-0.49008	1.84131	0.00000	2.75530	0.81718	20.45662	-0.14995	0.0	0.0	4.52290
28	58.77534	D	0.83331	17.30384	-3.39651	2.39346	0.39762	4.15975	0.84329	12.99913	2.29760	0.0	0.0	3.60543
29	59.27534	BF	0.83749	20.88147	-3.75875	2.59227	0.39762	4.56962	0.85000	10.82229	2.05608	0.0	0.0	3.28973
30	62.16496	DD	0.85357	33.67330	0.01782	3.18895	-0.00000	5.80287	0.91713	5.34167	0.11378	0.0	0.0	2.31120
31	63.36496	BF	0.85925	33.67330	-0.01782	3.18895	-0.00000	5.80287	0.95319	5.34167	-0.11378	0.0	0.0	2.31120
32	66.25457	D	0.87532	20.88147	3.75875	2.59227	-0.39762	4.56962	1.02032	10.82229	-2.05608	0.0	0.0	3.28973
33	66.75457	BD	0.87951	17.30384	3.39651	2.39346	-0.39762	4.15979	1.02703	12.99913	-2.29760	0.0	0.0	3.60543
34	69.64418	DDD	0.92347	7.59169	0.49008	1.84131	-0.00000	2.75530	1.05314	20.45662	0.14995	0.0	0.0	4.52290
35	75.64418	BD	1.06852	7.59169	-0.49008	1.84131	-0.00000	2.75530	1.10052	20.45662	-0.14995	0.0	0.0	4.52290
36	78.53379	D	1.11247	17.30384	-3.39651	2.39346	0.39762	4.15979	1.12663	12.99913	2.29760	0.0	0.0	3.60543
37	79.03379	BF	1.11666	20.88147	-3.75875	2.59227	0.39762	4.56962	1.13334	10.82229	2.05608	0.0	0.0	3.28973

QX = 1.11665962   XRMS = 2.62860553   QY = 1.13333621   YRMS = 0.0

TRANSITION GAMMA = 5.445947

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*** D      CYA    6  1 // C    C    C    C    C    C
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